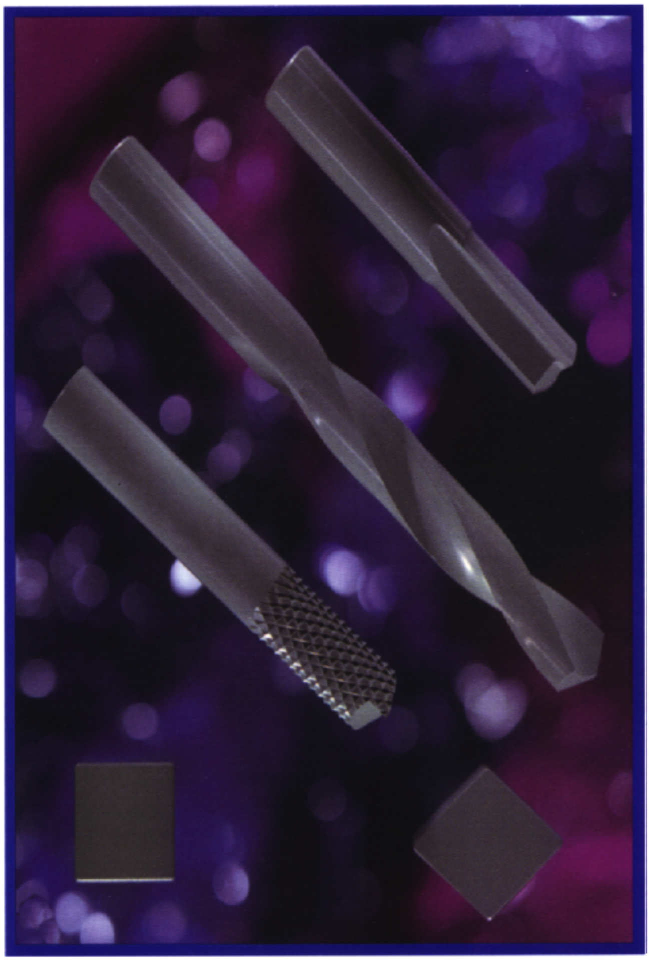
Ceramics

beyond pottery, whiteware, and dishes



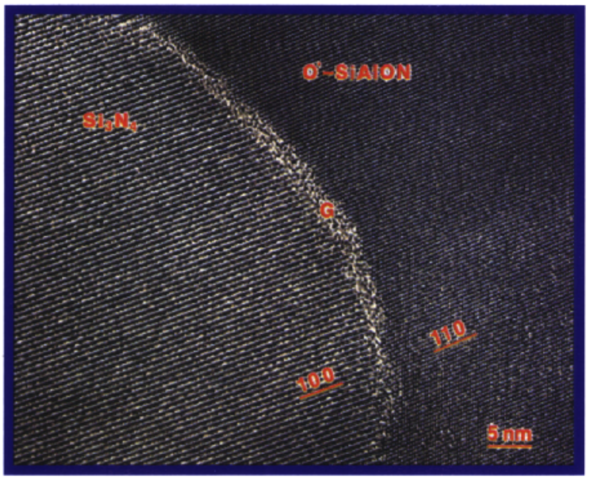
Researchers at Oak Ridge National Laboratory have developed a new tough ceramic that has had far-reaching effects on the cutting tool industry. Using these new ceramics, machining rates have been increased by up to 800 percent. The discovery of these ceramics, an alumina composite reinforced with silicon-carbide whiskers, was based on BES research into ways to toughen ceramics and supported by DOE's Energy Efficiency Programs. This material, which has been licensed to a number of companies, has current worldwide sales of over $30 million. The cutting tools shown here are from Advanced Composite Materials Corporation.

Ceramics keep their strength at high temperatures, are lightweight, and often have excellent thermal and electrical properties. But anyone who has ever dropped a dish knows why these brittle materials have not been more widely used. Although ceramics are never likely to replace metals in all applications, ceramics are now tough enough — thanks to BES-sponsored basic research on combatting brittleness — for use in hammers, high-speed cutting tools, engine turbines, and sports equipment.

One of the ways to toughen a ceramic is to reinforce it with fibers or small whisker-like additions, much like strengthening concrete with steel bars. Industry and others are now using BES models of toughening mechanisms, coupled with insights gained from characterizing the quality of the interfaces between the fibers and the ceramic matrix and the chemistry that goes on there, to make better ceramic automobile parts, cutting tools, and fabrication dies.

Structural ceramics begin with a powder, which is mixed with a liquid binder, shaped, and sintered at high temperatures. Electronic and optical applications often require large crystals with perfectly aligned atomic structures. BES is making a difference across the board. BES researchers have developed synthesis technologies for powder particles in high quantities, ceramics with uniform diameters and high purity, and methods to grow perfect crystals to larger sizes, all at low cost.

Because of their hardness, ceramic coatings — especially diamond and diamond-like coatings — help to reduce the wear of materials. At BES user facilities, characterizing the complex microstructures of these coatings is helping to gain a scientific understanding of how they work and is aiding in their commercialization.

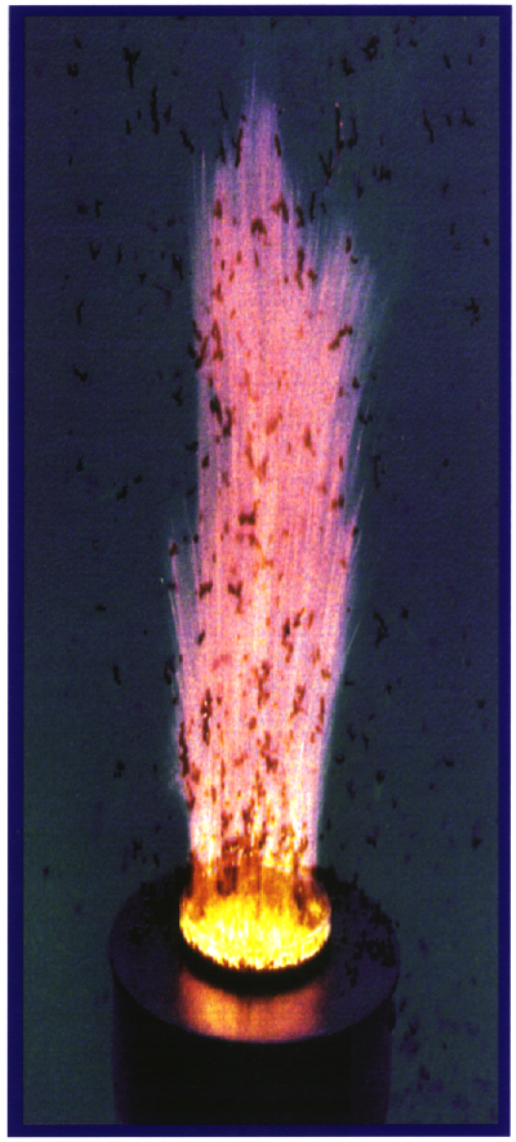


Atomic-Scale Microscopy

(left) The interfaces between reinforcing fibers and the brittle ceramic matrix frequently control the properties of a ceramic composite. Researchers from industry often use the sophisticated characterization tools available through the BES microscopy centers to correlate the properties of ceramics with the structure at the interfaces. Shown here is a high-resolution electron micrograph of a glassy layer in a silicon nitride-silicon aluminum oxynitride (SiAlON) composite from the University of Illinois Materials Research Laboratory.

Powders

(right) A process developed by Pacific Northwest National Laboratory allows simple, low-cost fabrication of clean ceramic powders with a fine particle size and good homogeneity. The winner of an R&D 100 Award, this process has now been commercialized by Praxair Specialty Ceramics for solid oxide fuel cells and other energy-efficient devices. The photo here shows the lab-scale powder production process.



Crystals

(above) Today ceramics are used in a number of electronic applications. Many of these applications require large, perfect "single crystals" of the ceramics. Researchers from Los Alamos National Laboratory and Advanced Ceramics Corporation have fabricated large single crystals — up to 10 mm in length and 5 mm in diameter-of silicon nitride. Potentially, these crystals can be used for insulators, imaging tips in scanning tunneling microscopes, and indenters for microhardness systems that operate at high temperatures.